

## DESCRIPTION

### ELECTROCONDUCTIVE CONTACT UNIT ASSEMBLY

#### TECHNICAL FIELD

The present invention relates to an electroconductive contact unit  
5 assembly which is suitable for use in contact probes and probe cards for  
testing semiconductor devices and wafers, sockets in such forms as LGA (land  
grid array), BGA (ball grid array), CDP (chip side package) and bare chip, and  
connectors.

#### BACKGROUND OF THE INVENTION

10 Conventionally, various forms of electroconductive contact units have  
been used in contact probes for conducting electric tests on electroconductive  
patterns of printed circuit boards and electronic component parts (open/short  
tests, environment tests and burn-in tests), sockets (including packages) for  
semiconductor devices (LGA, BGA, CSP and bare chip), and connectors.

15 When using such a socket for semiconductor devices, it is necessary to  
consider the fact that signal frequencies for semiconductor devices have  
significantly increased in recent years, and may be as high as hundreds of  
MHz. A socket for semiconductor devices that operate at such a high  
frequency level is required to use electroconductive contact units of low  
20 inductance and resistance and to be of a highly compact design in terms of  
mounting space.

#### BRIEF SUMMARY OF THE INVENTION

To accomplish such a task, and provide an electroconductive contact  
unit assembly having low electric inductance and resistance to meet the need  
25 in high frequency operation, and featuring a highly compact design, the

present invention provides an electroconductive contact unit assembly comprising a electroconductive contact unit in the form of a coil spring for resiliently contacting an object to be contacted, the contact unit being coaxially received in a through hole formed in an insulating support member, characterized by that: the through hole is shaped so as to have a reduced diameter portion at least at one axial end thereof; the contact unit in the form of a coil spring comprising a coil spring portion received in an intermediate part of the through hole and a pair of electrode pin portions, which are each closely wound at corresponding ends of the coil spring portion, and at least one of which is tapered or stepped in shape so as to be prevented from coming off by the reduced diameter portion; the contact unit being surface processed by highly electroconductive material.

Thus, a low electric resistance is accomplished because there are no parts connecting different components as opposed to the arrangement using an electroconductive needle member and an electroconductive coil spring, and a low electric inductance can be accomplished because the coil spring is closely wound and surface processed with highly electroconductive material, thereby providing a straight electric path along the axial direction of the closely wound portion of the coil spring. Because the electrode pin portions are retained and positioned by the cooperation between the tapered sections of the through hole and the tapered electrode pin portions, the axial length can be minimized and the contact unit is made more suited for compact design as opposed to the arrangement which slidably supports a needle member with a straight hole.

Preferably, the reduced diameter portion comprises a tapered hole section provided at each axial end of the through hole, and the pair of

electrode pin portions are tapered in shape and closely wound so as to be prevented from coming off by the tapered hole sections of the through hole. Thus, the retention and positioning of the both electrode pin portions of the electroconductive contact unit having two moveable ends can be accomplished, and the aforementioned advantages can be obtained.

According to a preferred embodiment of the present invention, the reduced diameter portion has a smaller inner diameter than the outer diameter of the coil spring portion, and is provided at each axial end of the through hole, and the other of the pair of electrode pin portions has a cylindrical shape which has a smaller diameter than the reduced diameter portion. Thus, when the objected to be contacted has a convex surface as is the case with a solder ball, the electrode pin portion having a cylindrical shape can be applied to the object to be contacted with a certain guiding action, and a stable contact with an object such as a solder ball can be achieved.

If the coil spring portion is wound at a uniform pitch, because the contact unit consists of closely wound portions and a uniform pitch portion, it can be formed with a simple coiling process.

If the electrode pin portions are each closely wound with a pre-stress, the contact between the adjacent turns of the coil wire can be improved.

If the surface processing is conducted after the coil spring portion and electrode pin portions are formed out of a wire member, the manufacturing process can be simplified, and the contact resistance of the closely wound portions can be minimized.

If the surface processing is conducted both before and after the coil spring portion and electrode pin portions are formed out of a wire member, the

contact resistance of the closely wound portions can be minimized.

#### BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is an enlarged sectional side view of an essential part of a socket for semiconductor devices embodying the present invention;

5        Figure 2(a) is a fragmentary perspective view of an essential part showing the coil wire which is gold plated;

Figure 2(b) is a view similar to Figure 2(a) showing the coil wire after it is closely wound;

10       Figure 2(c) is a view similar to Figure 2(b) showing the coil wire after it is gold plated once again;

Figure 3 is a view similar to Figure 1 showing the socket for semiconductor devices embodying the present invention during in use;

Figure 4 is a view similar to Figure 1 showing a second embodiment of the present invention;

15       Figure 5 is a view similar to Figure 3 showing the second embodiment of the present invention;

Figure 6 is a view showing a third embodiment of the present invention;

20       Figure 7(a) is a fragmentary perspective view of an essential part of a coil wire following a coiling process; and

Figure 7(b) is a similar view following a gold plating process.

#### DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Now the present invention is described in the following in more detail in terms of concrete embodiments with reference to the appended drawings.

25       Figure 1 is an enlarged sectional side view of an essential part of a

socket for semiconductor devices embodying the present invention. The illustrated socket comprises an insulating support member, for instance, consisting of a pair of insulating plates 1 which are made of plastic material and laminated one over the other. The support member integrally combining  
5 the two insulating plates 1 is provided with a through hole 2 extending across the thickness of the insulating plates 1, and an electroconductive contact unit 3 in the form of a coil spring is coaxially received in the through hole 2.

The through hole 2 comprises a linear and straight hole section having a uniform diameter and extending over a certain axial length in an axially  
10 intermediate part, and tapered hole sections 2a connected to either axial end of the intermediate part of the through hole 2 and each having an open outer end. Each tapered hole section 2a opens to the outside via a straight small hole section 2b having a uniform diameter and a prescribed length.

The electroconductive contact unit 3 in the form of a coil spring is  
15 formed by winding a coil wire made of spring material into a coil, and comprises a coil spring portion 4 received in the linear and straight section of the through hole 2 with a certain radial play, and wound at a prescribed pitch, and a pair of electrode pin portions 5a and 5b each consisting of a closely wound portion including a plurality of turns provided adjacent to the  
20 corresponding axial end of the coil spring portion 4 and having a same diameter as the coil spring portion 4 and tapered portion extending to the coil end. The tapered portion of each of the electrode pin portions 5a or 5b has a complementary shape with respect to the tapered hole sections 2a of the through hole 2, and the pointed end includes a portion having a smaller  
25 diameter than the straight small hole section 2b so that the pointed end may

project out of the straight small hole section 2b.

The electroconductive contact unit 3 in the form of a coil spring is received in the through hole 2 with the coil spring portion 4 placed under compression. For instance, the two insulating plates 1 are placed one over the other with the electrode pin portions 5a and 5b received in the corresponding parts of the through hole 2 formed in the insulating plates 1 so that the electroconductive contact unit 3 in the form of a coil spring may be assembled in the insulating plates 1 with the coil spring portion 4 placed under a pre-stress. It is also possible to place the electroconductive contact unit 3 in the through hole 2 without compressing the coil spring portion 4. This simplifies the assembly work.

Because the electrode pin portions 5a and 5b are tapered, simply by slightly fitting their free ends in the openings of the corresponding portions of the through hole 2 of the insulating plates 1, the electrode pin portions 5a and 5b are snugly received in the tapered hole sections 2a as the two insulating plates 1 are placed one over the other owing to the guiding action of the tapered hole sections 2a for the electrode pin portions 5a and 5b. Therefore, as opposed to the prior art which required each needle shaped electrode pin to be fitted into a corresponding hole, the assembly work is substantially simplified.

When the two insulating plates 1 are assembly to each other in close contact by using threaded bolts or the like, the resilient force of the coil spring portion 4 pushes the tapered portions of the electrode pin portions 5a and 5b against the tapered surfaces of the corresponding tapered hole sections 2a which are complementary to the tapered portions of the electrode pin portions 5a and 5b. Owing to the engagement between the opposing tapered surfaces,

the lateral shifting of the free ends of the electrode pin portions 5a and 5b can be favorably minimized. Therefore, when a plurality of such electroconductive contact units are arranged in a matrix as is the case with a socket, the projecting end of each electrode pin portion 5a or 5b can be arranged in a planar coordinate system at a high precision without any effort during the assembly work.

Thus, each electrode pin portion 5a or 5b of the electroconductive contact unit 3 in the form of a coil spring received in the through hole 2 can project out of the through hole 2 by a prescribed length under a rest condition. When the socket is in use, the electrode pin portions 5a and 5b are brought into contact with the circuit pattern 6a of the printed circuit board 6 and a terminal 7a of a semiconductor device which, for instance, may consist of a solder ball of a BGA 7

By applying a pre-stress to the electroconductive contact unit 3 in the form of a coil spring, the fluctuation in the load owing to the fluctuation in the deflection of each electroconductive contact unit or the fluctuation in the height of the object to be tested (circuit pattern 6a or terminal 7a) can be favorably minimized.

Figure 2 shows the mode of making the electroconductive contact unit 1 in the form of a coil spring according to the present invention. First of all, as shown in Figure 2(a), a coil wire 3a made of spring material as mentioned earlier is plated with gold which is a highly electroconductive material, and a gold plate layer 8a is formed over the entire outer surface of the coil wire 3a. The plating material is not limited to gold, but may also consist of Ni or Cu.

Then, the gold-plated coil wire 3a is subjected to a coiling process,

and formed so as to have the coil spring portion 4 and the electrode pin portions 5a and 5b as illustrated in Figure 1. The electrode pin portions 5a and 5b are each closely wound as illustrated in Figure 2(b), and the adjacent turns of the coil wire 3a in the closely wound portion is made to abut each other by applying a pre-stress to the coil wire 3a. As a result, in each of the electrode pin portions 5a and 5b which consist of closely wound portions, the adjacent turns of the coil wire 3a are in contact with each other via the gold plate layer 8a with a certain biasing force acting between them.

Referring to Figure 2(c), an additional gold plating process is applied to the assembly in the state illustrated in Figure 2(b), and a second gold plate layer 8b is formed over the entire outer circumferential surface of each closely wound portion. In this case also, the plating material is not limited to gold, but may also consist of Ni or Cu. As a result, the adjacent turns of the coil wire 3a is joined together not only by the mechanical biasing force but also by the second gold plate layer 8b which is formed continuously in the axial direction of the coil. This not only ensures a close contact between the adjacent turns of the coil wire 3a but also reduces the electric resistance which otherwise relies strictly on the close contact between the adjacent turns of the coil wire 3a.

Figure 3 shows a socket using a number of electroconductive contact units 3 in the form of a coil spring having the above described structure. In this case, because the electric signal is conducted solely through the electroconductive contact unit 3 in the form of a coil spring, and there is no connecting part such as a solder connection between the circuit board 6 and the BGA 7, the electric resistance can be stabilized. The coil spring portion 4 is necessary for bringing the contact unit into a resilient contact with the object



to be accessed, and the electric inductance  $H$  is related to the number of turns  $N$  of the coil wire 3a by the relationship  $H=AN^2/L$  where  $A$  is a coefficient and  $L$  is the length of the spring. Therefore, it can be seen that  $N$  should be as small as possible to minimize the electric inductance, and the spring portion  
5 preferably consists of about two turns, but may consist of up to 10 turns.

Because the adjacent turns of the coil wire in the electrode pin portions 5a and 5b are in close contact with each other under a pre-stress, and the assembly is entirely covered by the second gold plate layer 8b which continuously extends in the axial direction of the coil, the path of electric  
10 conduction in each of the electrode pin portions 5a and 5b extends linearly along the axial direction of the coil. Therefore, even though the coil wire is wound into a coil, the electric current does not flow along a spiral path, and this contributes to the reduction in the electric resistance and inductance.

Because the straight small hole section 2b connects the terminal end  
15 of the tapered hole section 2a of the through hole 2 to the outside, the free ends of the tapered electrode pin portions 5a and 5b would not be inadvertently caught by the terminal end of the tapered hole section 2a of the through hole 2. Owing to the shape of the straight small hole section 2b, a certain thickness is ensured to the opening, and this prevents inadvertent  
20 damage to the opening by contact with the terminal which consists of a solder ball.

Figure 4 shows a second embodiment of the present invention. The parts corresponding to those of the previous embodiment are denoted with like numerals, and are not described again. In this embodiment, a stopper 11  
25 similarly made of insulating material is laminated over the upper surface of the

upper insulating plate 1 as seen in the drawing, and a hole 11a is passed through the stopper 11 in registration with the through hole 2.

The lower electrode pin portion 5a in the drawing is tapered in a similar manner as in the previous embodiment, but the upper electrode pin portion 5c consists of a cylindrical portion having a smaller diameter than the coil spring portion 4, and is received in the hole 11a.

The mode of use of this electroconductive contact unit 13 in the form of a coil spring in a socket is illustrated in Figure 5 which is similar to Figure 3. As mentioned earlier, because the stopper 11 is laminated over the upper surface of the insulating plate 1, the lower surface of the BGA 7 engages the upper surface of the stopper 11, thereby determining the position of the BGA 7. Therefore, the distance of intrusion of the terminal 7a into the hole 11a is favorably controlled, and the electrode pin portion 5c can engage the terminal 7a with a constant load at all times. Therefore, the contact pressure of the electroconductive contact unit can be stabilized as compared with the case where the stopper 11 is not used, and a stable state of contact may be maintained when testing a large number of identical products.

In the second embodiment also, because the electric current does not flow along a spiral path in the electrode pin portions 5a and 5c, the electric resistance and inductance can be reduced.

Figure 6 shows a third embodiment of the present invention. The parts corresponding to those of the previous embodiments are denoted with like numerals, and are not described again.

In the third embodiment, there is no tapered hole section 2a which is connected to the intermediate part of the through hole 2. Instead, a retaining

plate 12 is laminated over the lower surface of the lower insulating plate 1 to prevent the lower tapered electrode pin portion 5a from coming off. The retaining plate 12 is formed with a small hole 12b which has a smaller diameter than the coil spring portion 4, and the electroconductive contact unit 3 in the form of a coil spring received in the through hole 2 is prevented from coming off by the axially intermediate part of the tapered electrode pin portion 5a abutting the edge of the small hole 12b.

The electrode pin portion 5b on the upper end of the coil spring portion 4 consists of a closely wound straight portion having a same diameter as the coil spring portion 4. Thus, even when the electroconductive contact unit 3 in the form of a coil spring is not retained in one direction, it can be used in a similar manner as in the other embodiments without any inconvenience by placing the assembly so that the tapered electrode pin portion 5a faces downward as shown in the drawing. In this case also, the electric current does not flow along a spiral path in the electrode pin portions 5a and 5d as was the case with the previous embodiments, and the electric resistance and inductance can be reduced.

Because the tapered hole section 2a is not required to be formed, the forming and assembling processes are simplified. For instance, during a time period in which products of a same model are required to be tested, a same relay board may be kept integrally attached to the upper surface of the upper insulating plate 1 with the upper electrode pin portion 5b kept constantly in contact with a terminal on the relay board. Because only the lower electrode pin portion 5a is required to be accessed each of the products to be tested, the electroconductive contact unit 3 in the form of a coil spring is allowed to

undergo a cyclic compression without risking the dislodging of the contact unit from the assembly. This contributes to the reduction in cost.

The gold plate layer 8a was formed prior to the coiling process in the embodiment illustrated in Figure 2, but the coil wire 3a may be subjected to the coiling process without any gold plating process so that only a single gold plate layer (corresponding to the second gold plate layer 8b) is formed over the surface of the assembly.

For instance, as shown in Figure 7(a), the coil wire 3a may be subjected to a coiling process so as to form a coil spring portion 4 and electrode pin portions 5a and 5b which consist of closely wound sections as was the case in the previous embodiments. A gold plating process is applied to the assembly in the state illustrated in Figure 7(a), and a gold plate layer 8b is formed over the entire outer circumferential surface of each closely wound section. In this case also, the plating material is not limited to gold but may consist of Ni or Cu.

In either case, the material for the coil wire 3a may be selected freely without regard to the electric conductivity, and may consist of inexpensive spring material.